

TECHNOLOGICAL, ECONOMIC AND ECOLOGICAL ASPECTS OF SELECTIVE COAL MINING FROM ULTRA-THIN SEAMS IN CONDITIONS OF UKRAINE

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ТЕХНОЛОГІЧНІ, ЕКОНОМІЧНІ ТА ЕКОЛОГІЧНІ АСПЕКТИ СЕЛЕКТИВНОГО ВИДОБУВАННЯ ВУГІЛЛЯ З НАДТОНКИХ ПЛАСТІВ В УМОВАХ УКРАЇНИ

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ABSTRACT

Purpose. At present one of the topical problems associated with coal seams mining is the issue of induced wall-rock coal-cutting with stone, which results in coal getting clogged with refuse stone and turning into the rock mass. All mines of Western Donbas produce coal with average ash content of 31 – 49%. Selective mining can become a solution to this problem as it allows to incorporate reserves with unconventional thickness that are in the mine balance sheet. The main objective of the present research is to substantiate selective technology of coal extraction applicability for mining of ultra thin coal seams in conditions of Ukrainian mines.

Methods. Hazardous substances' emissions into the atmosphere arising from implementation of bulk technology of coal extraction are estimated by analytical method.

Findings. Consequences of the increase in power plants' production capacity achieved by utilizing low-ash coal extracted by selective technology are presented.

Originality. The research looks into economic efficiency of implementing selective extracting technology for mining reserves with unconventional thickness in Ukrainian mines, particularly in Western Donbas.

Practical implications. The conducted analysis demonstrated that implementation of new technology will allow to resolve complex issues of coal quality increase, maintenance, reinforcement and reuse of mine workings, backfilling of worked-out area and improvement of ecological situation in coal mining regions.

Keywords: selective technology of coal extraction, waste-disposal dump, harmful substances emission, worked-out area, coal heat combustion, coal beneficiation, economic effect

1. INTRODUCTION

Following a comprehensive overview of the current situation in the Ukrainian coal industry, the specific issues of low grade seam underground mining are presented. Due to the significant amount of rock (waste) as part of many of such seams the application of selective mining technologies is assessed. High ash content in coal is causing various negative issues, beginning from mining at the coal face up to the marketing of the product (Bondarenko, Kharin & Antoshchenko, 2013). Finally, waste rock needs to be disposed in an environmentally acceptable way (Falsztinskij, Diczkowskij &

Łozinskij, 2010). Selective mining and adapted ways of transportation could enable the coal producer to separate parts of the raw coal within the extraction area and to leave them directly as backfill underground (Journal, 1980; Vladyko, Kononeko & Khomenko, 2012). Economic parameters of the technologies that could be introduced into the mining industry of the Western Donbass region, are being calculated. They will be compared with commonly used bulk materials handling technologies. Consequently, the overall advantage of selective mining under the specific Ukrainian conditions is proved.

2. THE UKRAINIAN COAL INDUSTRY

Before the outbreak of war in Eastern Ukraine, the country was self-sufficient in its coal supply. In 2013, Ukraine produced over 60 million tons of coal at a capacity that was maintained until the first half of 2014. Because of the military occupation of some Ukrainian territories, about 66 coal mines were lost. About half of the Ukrainian thermal power stations are using locally produced anthracite. The government now aims to modernize the coal mining sector and to transform the industry into an unsubsidized and self-sustainable sector with a projected coal production of about 43 million tons per year.

3. GENERAL BACKGROUND

Selective mining in combination with direct backfill was the standard technology in coal mining during the time when mineral extraction by hand-tools was in common use. However, those selective methods had become more and more neglected when mine mechanization started to replace expensive manpower. Nevertheless, some selective mining technologies including backfilling were still used in some cases of longwall operations world-wide. A typical arrangement for direct waste rock backfill in the longwall section was the “campacker”, used in the UK. Germany coal mines successfully used pneumatic backfill technologies until the 1980’s, but in those cases the waste rock was transported from the coal-washing plant back underground and pneumatically put into the longwall’s goaf area. In 1975, as part of a joint research program initiated by the German Minister for Research and Technology, a study of the Clausthal Technical University looked into the issue of backfill technologies with the aim to reduce the waste content in run-off-mine coal (Knissel & Leschhorn, 1975). This study compared the coal production costs with different waste-rock content in the raw coal. It was found that the raw coal share of more than 40% was creating high additional costs at all stages of the process chain, especially through additional wear on underground conveyors, chutes, bunkers, the skip hoisting system and in the washing plant. In addition, production of raw coal at a higher than needed level significantly increases energy consumption. The last but not the least are waste dumps creation costs and environmental issues.

4. SITUATION IN UKRAINE

The above-described problems have not changed since then especially as far as Ukrainian coal mining industry is concerned. Currently the situation has become even more problematic because of the enormous pressure on production costs caused by the worldwide oversupply of coal and dramatically falling coal prices. Many coal mines, even in countries with particularly low-cost production, are struggling to survive. Since low coal seam mining is generally regarded as more expensive than mining of higher coal seams, the situation is critical for the Ukrainian coal industry where there is an urgent need to increase the efficiency of thin-seam mining especially in the Western Donbass area. About 70% of the total coal resources are associated with the seam thickness range of 0.5 – 0.8 m. The technically recoverable coal resources are abundant and may be sufficient for

150 – 200 years of sustainable production at an annual rate of about 100 million tons. Analysis of the present day leading Ukrainian coal producers’ performance shows that coal quality is not the top priority and that there is lack of environmentally appropriate procedures of waste disposal. Mine waste disposal on the surface involves allocating land near the coal processing plants, such as dump areas or abandoned pits for solid rocks and dams for slimes and slurries.

Mines all over Ukraine used to produce about 100 million tons (now roughly 85 million tons) of coal before the war. They generated about 55 – 60 million tons of waste which had to be dumped into their sites. Currently more than 1.7 billion cubic meters of waste from previous mining activities are piled in 1063 waste dumps, covering a total area of more than 7.200 hectares of Ukrainian land. What makes things even worse is the fact, that more than 20% of those disposal dumps are affected by spontaneous combustion. They are located mostly in the Donetsk coal basin.

The pre-war production of the Western Donbas mines was about 18 million tons, which resulted in 7 million tons of mine waste to be dumped on surface areas annually. In theory, it means that only 7 out of 10 mines in the Western Donbas were really extracting (clean) coal while the other 3 mines of “DTEK Pavlohradvuhillia” were only producing useless rock associated with all the costs of the coal processing chain.

5. WASTE ROCK ISSUE IN DETAIL

The main source of coal dilution by waste rock is extracting the bottom-layer of the seam that generally consists of siltstone and mudstone. Mechanized bulk mining methods which need a certain operation height for effective extraction are used to cut those layers simultaneously. The resulting dilution of the produced coal was commonly neglected. Currently, the run-off mine coal from typical Ukrainian mines has ash content between 49% and 52%. If the ash content increases by 1% , the coal caloric value decreases by 80 kcal/kg. Caloric value losses before coal beneficiation exceed 2000 kcal/kg. This unnecessary decrease in the quality of the salable coal is the result of reduced washing plant efficiency. There are also unreasonable expenses resulting from excess transportation activities and mine waste handling efforts (Fig. 1).

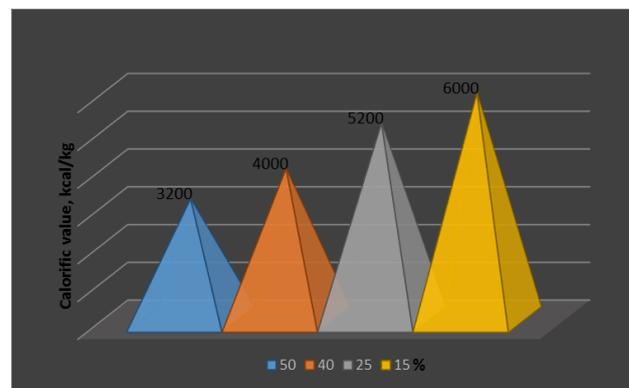


Figure 1. Decreasing caloric value of coal related to ash content

6. EMISSIONS FROM THE COAL INDUSTRY

In addition to emissions from coal producing mines, Ukraine's coal consuming plants are releasing about 1.1 million tons of material into the atmosphere. Those emissions (all values are rounded), such as dust particles (38 thousand tons), sulfur oxides (122 thousand tons), carbon oxides (150 thousand tons), nitrogen oxides (9 thousand tons), hydrocarbons (465 thousand tons) and other gaseous substances (256 thousand tons) are regarded as environmentally problematic. The bulk of those emissions come mainly from coal combustion and coal drying facilities in coal processing plants, where coal is used as a fuel (User, 2016).

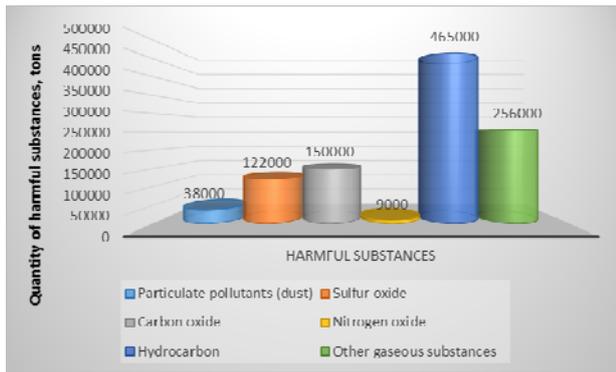


Figure 2. Annual releases of emissions from coal processing plants

In theory, complete avoidance of waste in the raw coal would result in the inherent ash level of 15 – 18%. Any reduction of ash through selective mining helps to solve economic, ergonomic and ecological issues.

The idea of separate extraction of coal and barren rock is not new to the mining industry. Numerous technologies for selective mining and underground rock disposal have been tried globally. A new attempt will soon be undertaken in longwall operations of the “Karahandaugol” Association, where sequential extraction of coal and interburden layers from top to bottom will be done by a series of shearers. This extraction method was successfully applied in mining of oil-shale deposits with the primary extraction of oil-containing shale and the follow-up extraction of intervening rock during the shearer's return trip. The result was a significant upgrade of product quality through reduced dilution, following a further benefit to the liquefaction process. However, the technologies that apply to a layer-by-layer extraction of coal and rock are not widely used in the coal mining industry (Buzilo et al., 2012).

This lack of acceptance is mostly related to the target of maximal coal production rather than better product qualities. As a result, beneficiation plants are delivering highly diluted coal with almost double the required content of ash (waste) to the end user.

7. THE PROPOSED MINING TECHNOLOGY

Selective mining method was developed in the late 1980's, however the technology has not become a widespread practice because priorities of coal mining enterprises still rest with increasing extraction volume rather than raising the quality of initial products.

The technology of selective mining of thin and very thin flat and inclined coal seams is intended for improving the quality of extracted coal in faces with cutting of wall rocks, and also for expanding the application area of existing shearers complexes to effectively mine seams with thickness from 0.4m to 0.9m.

Selective mining is meant as mining of coal seam and cutting rock separately in time or space with separate transportation of mineral and waste rocks. The technology is based on implementation of mechanized complexes of shearers that are intended for mining thin coal seams: KM97, KM87, KM103 and KD80.

Application of the existing mining equipment adds to the technology flexibility, for instance, it allows shifting from the separate mining to the bulk one at any time and vice versa, without any additional expenses in a wallface. However, this technology also has certain downsides. As a rule, mining of one coal strip is carried out via two passes of a shearer: one pass on coal, the other on the rock. The speed of shearer's advance during separate mining considerably increases, and the time of a single cycle increases on average by 1.5 times. To ensure the required intensity of seam mining, technological options for the separate mining of coal and wall rocks for one pass of a shearer are developed.

Nowadays, complex 1K101U seems to be the most adapted for selective mining, as its design allows to fulfill seams both for one and two passes of a shearer (Fig. 3).



Figure 3. General view of shearer 1K101U

Shearer 1K101U is intended for mining coal on seams with thickness from 0.4m to 1.2m at a slope angle of 35° and coal resistance to cutting up to 270 kN/m.

During its work, a shearer leans from the face on the cleanup plowshare of the conveyor by means of two hydraulic cylinders regulated by height, and from the worked-out area – on round guide that is established on the goaf part of the conveyor. The shearer works without stable holes at the conveyor heads which are taken out on a roadway. The cutting part of the shearer is located between screws in a face slope. Control of the shearer is performed from the panel that is placed on its portal.

8. BENEFITS OF THE SYSTEM

Versatile research proved that selective coal extraction aimed to reach minimal ash content is characterized by various advantages (Buzilo et al., 2012; Denisov & Mamaykin, 2010; Astafiev & Shapovalov, 2013). At an inherent ash content of 25%, i.e. about 399 grams of coal is needed to produce one kWh of power compared to 704 grams at 50% ash (Fig. 4).

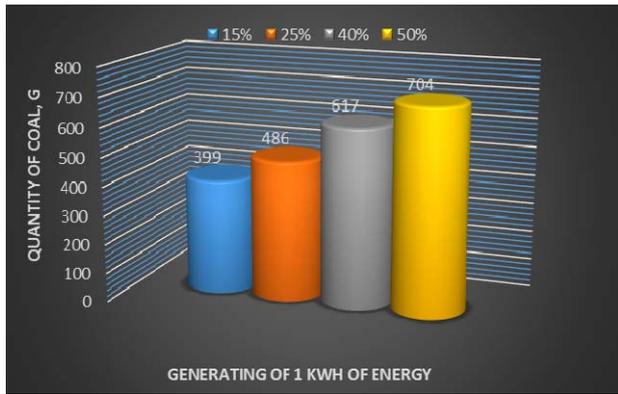


Figure 4. Specific consumption (g/kWh) of coal with ash content from 15 to 50%

In other words, combustion of one ton of coal with ash content 15% can produce about 2.5 MWh of electric power which would decrease to 2.06 MWh in case coal with 25% of ash is used and drop down to 0.96 kWh for the coal with 50% of ash (Fig. 5). It is obvious that high ash dilution of coal leads to respectively worse efficiency of the coal-fired power plants.

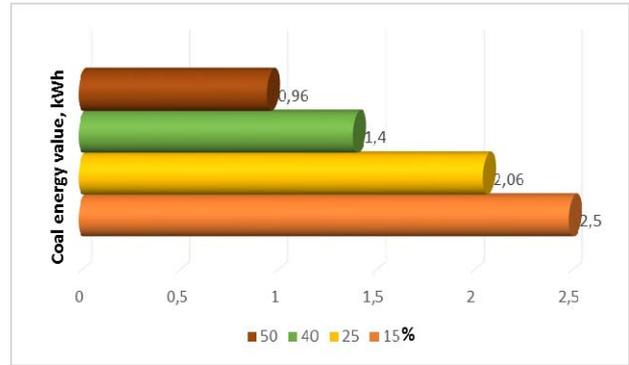


Figure 5. Recoverable electric power from coals with ash content between 15 and 50%

The theoretical plant efficiency using clean coal with inherent ash content would be 0.36 (36%).

This efficiency will fall by more than 13% to 31.8% when 40% ash coal is used. As a result, the use of clean coal instead of 45 – 50% ash coals leads to total cost savings of up to UAH 20 million (€ 0.8 million).

The economic advantage of selective coal extraction compared to full seam extraction in Ukrainian conditions is unquestionable (Table 1).

Table 1. Economic implications of selective mining compared to bulk mining of coal in Ukraine in UAH (€) per ton of produced coal

Process Activity	Bulk Mining Expenses	Selective Mining Expenses	Economic Advantage
Conveyor Transport	UAH 33.3 (€ 1.33)	UAH 10 (€ 0.4)	UAH 23.3 (€ 0.93)
Locomotive Transport	UAH 22.2 (€ 0.88)	—	UAH 22.2 (€ 0.88)
Shaft Hoisting	UAH 24.6 (€ 0.98)	UAH 7.4 (€ 0.3)	UAH 17.2 (€ 0.68)
Surface Transport	UAH 133.4 (€ 5.34)	—	UAH 133.4 (€ 5.34)
Coal Beneficiation	UAH 70.6 (€ 2.82)	—	UAH 70.6 (€ 3.53)
Re-use of Preparatory Mine Workings	—	UAH 20.57 (€ 0.82)	-UAH 20.57(-€ 0.82)
Additional Expenses for Backfill Operation	—	UAH 72.6 (€ 2.9)	-UAH 72.6 (-€ 2.9)
Total Cost Reduction			UAH 191.6 (€ 7.64)

Consequently, the total decrease of cash-costs (operation costs including shipping to local customers) equals to UAH 191.6 (€ 7.64) per ton of salable coal product.

9. CONCLUSIONS

The proposed technology of selective mining means extraction of coal seam and coal cutting with stone separated in time and space including separate transportation of empty rocks and mineral deposit. Using existing mine equipment makes technology rather flexible, i.e. makes it possible if necessary to shift from separate extraction to bulk one and vice versa, without any additional expenses. The main benefits of the technology allow to get:

- more than 500 million tons of coal additionally from Western Donbass deposits which can be extracted by avoiding underground protective coal pillars;
- significant cash-cost savings of 20 – 25% through low ash production compared to existing procedures;
- reduction of the specific coal consumption to generate electricity from 487 g/KWh (at 25% ash) to 300 g/KWh (at 15% ash);

- possibility of clean coal production with ash content not higher than 15 – 18%;
- substantially reduced emissions of hazardous particles and gases into the atmosphere;
- less waste rock handling with the benefit of energy saving and less wear;
- better surface conditions through less subsidence from mining;
- conservation of land by reducing the areas of rock-disposal dumps;
- overall economic advantages and public acceptance for the coal mining industry in Ukraine.

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ABSTRACT (IN UKRAINIAN)

Мета. В даний час однією з найбільш актуальних проблем при відпрацюванні вугільних пластів є питання про вимушене присікання бокових порід, внаслідок чого вугілля засмічується породою і перетворюється в гірничу масу. В середньому всі шахти Західного Донбасу видають на поверхню вугілля із зольністю 31 – 49%. Вирішенням цієї проблеми може бути перехід на селективне виймання, яке дозволить залучити некондиційні за потужністю запаси, що знаходяться на балансі шахти. Основною метою даної роботи є обґрунтування доцільності застосування селективної технології видобування вугілля для відпрацювання вельми тонких вугільних пластів в умовах шахт України.

Методика. Проведена оцінка викидів шкідливих речовин в атмосферу від використання валової технології видобутку вугілля аналітичним способом.

Результати. Наведені результати збільшення виробничої потужності електростанцій за рахунок використання низькозольного вугілля, видобутого при використанні селективної технології.

Наукова новизна. Обґрунтована економічна ефективність впровадження селективної технології видобування для відпрацювання некондиційних вугільних запасів шахт України, зокрема Західного Донбасу.

Практична значимість. Проведений аналіз показав, що впровадження нової технології дозволить комплексно вирішити питання підвищення якості вугілля, підтримки, кріплення й повторного використання виробок, закладки виробленого простору та поліпшити екологічну ситуацію у гірничодобувних регіонах.

Ключові слова: селективна технологія видобутку вугілля, породний відвал, викид шкідливих речовин, вироблений простір, теплота згорання вугілля, збагачення вугілля, економічний ефект

ABSTRACT (IN RUSSIAN)

Цель. В настоящее время одной из наиболее актуальных проблем при отработке угольных пластов является вопрос о вынужденной присечке боковых пород, вследствие чего уголь засоряется породой и превращается в горную массу. В среднем все шахты Западного Донбасса выдают на поверхность уголь с зольностью 31 – 49%. Решением этой проблемы может быть переход на селективную выемку, которая позволит вовлечь некондиционные по мощности запасы, находящиеся на балансе шахты. Основной целью данной работы является обоснование целесообразности применения селективной технологии добычи угля для отработки весьма тонких угольных пластов в условиях шахт Украины.

Методика. Произведена оценка выбросов вредных веществ в атмосферу от использования валовой технологии добычи угля аналитическим способом.

Результаты. Приведены результаты увеличения производственной мощности электростанций за счет использования низкозольного угля, добытого при использовании селективной технологии.

Научная новизна. Обоснована экономическая эффективность внедрения селективной технологии добычи для отработки некондиционных угольных запасов шахт Украины, в частности Западного Донбасса.

Практическая значимость. Проведенный анализ показал, что внедрение новой технологии позволит комплексно решить вопросы повышения качества угля, поддержания, крепления и повторного использования выработок, закладки выработанного пространства и улучшить экологическую ситуацию в горнодобывающих регионах.

Ключевые слова: селективная технология добычи угля, породный отвал, выброс вредных веществ, выработанное пространство, теплота сгорания угля, обогащение угля, экономический эффект

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